UCID- 20580

# PLANNING FOR A MAJOR FACILITY ON THE BASIS OF EXPERIENCE WITH MFTF

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January 14, 1986

Lawrence Livermore National Laboratory



Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

| Price Code | Page Range |
|---|---|
| A01 | Microfiche |
| **Papercopy Prices** | |
| A02 | 001-050 |
| A03 | 051-100 |
| A04 | 101-200 |
| A05 | 201-300 |
| A06 | 301-400 |
| A07 | 401-500 |
| A08 | 501-600 |
| A09 | 601 |

PLANNING FOR A MAJOR FACILITY
ON THE BASIS OF EXPERIENCE WITH MFTF

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## ABSTRACT

This report is intended as a guide for those who may undertake to satisfy equipment and hardware requirements for a project or experiment from the conventional-facility vantage point. Conventional facility refers to that which remains after a project or experiment has been completed and is analogous to a house that is left after the tenants have moved out. This report discusses the techniques that proved helpful in refining the requirements and lowering cost during the construction of MFTF. These techniques included the use of models, the coordinating of parallel construction activities, and a method for handling minor construction needs.

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## INTRODUCTION

The MFTF project's principal building, Building 431, was built in the early 1950s. To convert the building for MFTF use required renovating portions of the building and increasing its size to accommodate the equipment necessary for the project. In addition to the modification of Building 431, other major construction was necessary for the MFTF project:

- Building 439 was built for the control system and associated computer.
- Building 440, a technician support shop for the project, was added as an extension to Building 439.
- Building 433 was constructed to house the cryogenic compressors and nitrogen reliquifier necessary to accommodate the increased scope of the project with MFTF-B .
- Building 437, a mechanical support building for the project, was built as an extension to Building 432 and will carry that number.
- Building 543, an office building, was constructed to house the increased staff of the MFE Division due to the MFTF project.
- A 230-kV substation and associated power supply yard were constructed for the neutral beam power supplies and microwave heating power supplies.

This report is intended as a guide for those who may undertake a similar task--that is, the satisfaction of equipment and hardware requirements for a project or experiment from the conventional-facility vantage point. Conventional facility refers to that which remains after a project or experiment has been completed and is analogous to a house that is left after the tenants have moved out. It will address the following areas that are involved in that process:

- Defining the requirements.
- Reviewing conventional facility considerations.
- Implementing relocation of facilities and people to make way for demolition, new construction, and modifications.
- Accomplishing minor construction.
- Coordinating construction.
- Modeling.
- Reviewing.

- Determining impact on utilities.
- Establishing storage, staging, and field fabrication areas.
- Scheduling and estimating.

In the report, the term "client" refers to the project engineer who supplies the requirements, the user who will occupy the space, and the project manager who is responsible for the total budget of the project.

## DEFINING THE REQUIREMENTS

The first objective is to define the requirements; how much space, electrical power, mechanical utilities, or other special provisions will the conventional facilities have to provide. When establishing the requirements, it is beneficial to visualize the space to be occupied as a suspended volume in air; everything necessary to the functioning of the equipment inside that space must be supplied. Utilities and building functions, such as electrical power or the ability of the floor to support a load, are frequently taken for granted. Visualizing the space as a isolated volume helps to identify all of the requirements.

The MFTF construction program was project-engineer oriented. All requirements for each of the systems, referred to as "special facilities," were submitted by the project engineer for that system. Each project engineer has individual expertise, which may or may not include an awareness of what is involved in supplying needs from the conventional-facility vantage point. To help identify all such needs, a check list was used to assist the project engineers consider overlooked items that might be needed to make their system work. Table 1 shows a check list similar to the one used. A standard form was used to collect the requirements from the project engineers. This helped in categorizing the needs for design of the distribution systems. A form similar to the one shown in Fig. 1 was used.

Where a facility exists, obtain the drawings of the area to learn the makeup and content of the floors, walls, and ceiling. Review the correctness of these drawings before initiating any modifications; there may be some surprises. Rebar or structural steel may be located in the path of new penetrations. Utilities may exist in the walls or floors in locations that would impact new construction. Where possible, new requirements should try to take advantage of existing utilities and space. However, you should also

Table 1. Check list for requirements.

| Item | Remark |
|---|---|
| ACCESS ROOM | Is there clearance to cabinets for equipment installation and maintenance? Is there clearance over the equipment? Will room for assembly or maintenance fixtures be required? |
| ACOUSTIC | Does the equipment generate noise that would be annoying to the user or a neighbor? Refer to OSHA standards for acceptable noise levels. |
| AUDIO LINKS | Are telephones or intercoms needed? |
| CLEAN POWER | Should the electric power be free of power surges that could be generated by other users on the same buss? |
| COOLING AIR | How will heat generated by the equipment be removed? |
| COOLING WATER | Will Low-Conductivity Water (LCW) be required? |
| DAILY SERVICE | Will other than the project personnel need access to the equipment? |
| DUST | Will air filtration be required? |
| FIRE PROTECTION | Is the existing sprinkler and smoke removal system adequate? |
| FLOOR LOADS | Has the total wet load of the equipment been tabulated to ensure that it does not exceed building support capabilities? |
| GAS | Does the equipment produce gas that will have to be exhausted? Will a gas feed from another area be needed? |
| GROUNDING | Are there special requirements for the electrical grounds? |
| HAZARDS | Equipment may present many types of hazard, including electrical shock, high-energy storage, and radiation. Have these been reviewed to ensure personnel safety? |
| HIGH CURRENT | Will the equipment cause line surges that could affect another user on the line? |
| HIGH VOLTAGE | Will the equipment generate transients that could influence neighboring equipment? Is there enough space between points of high voltage and ground? |

Table 1. Continued.

| Item | Remark |
|---|---|
| INTERLOCK | Will the space require an access interlock? Will the utilities that supply the equipment require an interlock to ensure that they are operational? |
| LIFTING EYES | Are there handles or lifting eyes on the equipment to aid in installation? |
| LIGHTING | What are the ambient lighting requirements? |
| MAGNETIC FIELD | Will the equipment produce a magnetic field? Will it be placed in an area where a field exists that could influence its operation? |
| OIL | Does the equipment involve the use of oil that should be contained in the event of a spill or leak? Will additional fire protection be required? |
| RADIATION | Will shielding be required to attenuate radiation? |
| SEISMIC | Has the equipment mounting design considered the effects of an earthquake and the building's response to one? |
| SPARE PARTS | Has room been provided for the storage of spares? |
| VENTILATION | Will noxious gas discharge or air conditioning for personnel comfort require special ventilation? |
| VIBRATION | Will the equipment require vibration damping? |
| VIDEO LINK | Will remote monitoring of the area be required for operation or diagnostics? |

CONVENTIONAL-FACILITY FURNISHED REQUIREMENTS

System ______________________________

Item ______________________________

Location ______________________________

Size (LWH) ______________________________

Weight ______________________________

Function ______________________________

______________________________

(Supply sketch showing location of equipment and total wet weight.)

Electrical

Voltage/phase ______________

kVA ______________

Clean power _______ Pulsed power _________

Duty factor _______ Power factor _________

Distribution panel location (attach sketch) _______

Mechanical

LCW _________

Heat load to be removed (kW) _________

gpm ______________

Duty factor __________

Supply/return location (attach sketch) __________

Compressed air

cfm ___________

Pressure (psig) ___________

Location (attach sketch) ___________

Air conditioning

Heat to air to be removed (kW) _________

Relative humidity ___________

Temperature range ___________

Structural

Additional floor support required? Yes _____ No _____

Beneficial occupancy date __________

Figure 1. Sample of form used to list conventional-facility requirements.

evaluate the long-run cost of this option vs that of providing new service and space.

Collecting and reviewing the requirements is an iterative process. Once you have selected the method of implementing the requirements, it is essential to review them with the project engineer, the ultimate user, and if necessary, a review board before negotiating a contract for modifications or new construction. In an R&D environment, new systems can change rapidly before they come to fruition, and what was originally requested may prove to be inadequate. While the stress level of those responsible for supplying the conventional facility needs would be lower if the original requirements did not change, this does not occur frequently. Expect changes, remembering that it is the requirements of the project that are paramount and not the facility itself.

## CONVENTIONAL FACILITIES CONSIDERATIONS

In establishing the requirements for new equipment, you may realize some savings by determining what usable service the on site utility systems can provide. Thus, before collecting the requirements, it is advisable to know the specifications and capacities of existing systems for LCW, electricity, compressed air, and any other utilities that are present (such as telephone, natural gas, liquid nitrogen, city water, and sewer). When you have collected the requirements for the new system, review the services that already exist with the client to determine if they are adequate. Also, make information on existing systems, especially criteria governing floor loads and cooling capacity from either low-conductivity water or ventilation systems, available to the designers of the new special facility equipment. Again, it is recommended that you visualize the building as being suspended in air and that you list all of the utilities feeding it.

An additional benefit from determining the existing electrical or mechanical distribution networks of a building is that this will enable you to know how the building works. Walk through the facility and determine the location of distribution system takeoffs, light controls, water turnoffs, ventilation system intake and exhaust ports, and the water supply for the fire sprinkler system. Not all utilities in LLNL buildings are well documented, and change of personnel often results in loss of information. For instance, the phase rotation of multiple-phase receptacles has been found to vary from one side of a building to the other, which could be devastating to portable motors that are moved from one area to another. Thus, it is advisable to check multiple phase receptacles to ensure that they have the same phase rotation.

The onsite utilities do have limits; they are not inexhaustible. LLNL has an electrical system distribution capacity of approximately 100 MW and a LCW system cooling capacity of nearly 60 MW. Electrical energy use is being looked at very closely and methods of recharging the programs are being formulated. Large programs can economize by combining and taking advantage of equipment duty cycles. Distribution systems should take advantage of equipment use factors so that they are not designed to feed all units full power 100% of the time. If it is possible to phase an operation so that different major loads are not on line at the same time, you may realize some economies. Offpeak power is less expensive to use, and this may be a consideration in determining when to operate the facility or equipment.

Plant Engineering must be informed of all changes to a building either by direct involvement or by having them review what is being proposed. Plant Engineering must also review and approve changes to the site distribution systems. Adequate documentation is needed so that whoever inherits the system (facility) will know what is there and how the distribution system is fed. Changes to existing structures should be reviewed and certified, if need be, to ensure that what happens on one floor will not weaken or influence other floors.

Floor loading in most multiple-story buildings is 125 to 150 pounds per square foot. Review the total floor loading to ensure that the floor capacity is not exceeded. For concentrated loads, pads could be supplied that would spread the load to meet the building specifications. In some cases, stiffners might be added to increase the capacity in a particular location.

If several new systems require service, take advantage of common distribution systems, if possible. Before turning the requirements over to the Conventional Facility design team, prepare a block diagram showing what each major system or piece of equipment will require. This diagram may provide the logic for the distribution system design.

Finally, if the changes to a facility are reviewed with Fire Safety personnel before major design proceeds, satisfaction of the fire protection requirements may be simplified. Fire Codes change, and LLNL has accumulated a wealth of experience on what works and what does not work for a variety of buildings. Soliciting their comments early in the design could result in savings for the project.

## RELOCATION, DEMOLITION, CONSTRUCTION, AND MODIFICATIONS

### RELOCATION

One of the more painful tasks in reconfiguring an existing facility is relocating personnel and equipment in preparation for the modifications. Before work proceeds, it should be made clear who will pay for relocation and what will be provided.

Equipment that has been in an area for a long time, say five to ten years, will probably need upgrading to meet new codes. This could be an unexpected expense for the relocation. Also, some services will have to be continued during the relocation, which could involve an outside contract to supply the service at an additional expense.

There can be a positive side to the relocation process. This occurs when the owner of the service to be relocated has planned for an upgrade or reconfiguration and has prepared an estimate for the work. Moving the equipment from one area to another provides a clean break and allows the upgrading of the equipment to proceed in an organized manner.

### DEMOLITION

It is advisable to contract for the demolition of buildings and other facilities in an area in preparation for new construction separately from the new construction itself. Some of the reasons for this are:

- The demolition contract can be better defined and more easily managed when separate.
- Under a separate contract, demolition cost are usually billed at a lower rate than when combined with new construction.
- The separate contract also permits a cleaner bid package for the new construction. The bidders for new construction know what work

is to be done, and there are no hidden utilities or support structures that must be dealt with.

- The separate demolition provides a clean and clear space from which to proceed with the design of the new construction.

Members of an outlaw motorcycle gang carried out part of the demolition for MFTF and did a creditable job. The area to be demolished was well defined by markings (red: remove; green: leave in place) and by prints defining the area.

## CONSTRUCTION

Major construction for the MFTF project was managed through Plant Engineering. A Construction Manager was assigned, and a design team was established to organize the requirements into a specification package, which was then put out for bid. LLNL's method of selecting a design firm for this type of construction project is not direct. Bids are accepted from qualified Architect and Engineering (A&E) firms or from construction firms with design capability. The capability, areas of expertise, and performance record of bidding firms are reviewed, and a selection is made. After the company is chosen, the price for the contract is negotiated.

The design package is then developed in two phases: Title 1 and Title 2. Title 1 is a preliminary layout of the facility that gives a general view of how the requirements are to be met and allows an evaluation of whether the design is on the right track. Title 2 is a complete construction package that includes all the details left out of Title 1. Both packages should be reviewed by the client before construction proceeds. If the package is put together by an A&E firm, it will be advertised for bid in "The Daily Pacific Builder" or similar publication. The successful bidder is selected in the conventional way from those that respond. It is very important that the actual user of the facility review the package before the job is bid, since there will be details such as where utilities are located or how doors swing that may not be apparent to the Plant Engineering or A&E design teams.

When a bidder is selected and construction starts, a Construction Inspector will be assigned to follow the day-to-day progress of construction. Only the Construction Manager or the Construction Inspector can direct the contractor to make changes. It should be emphasized, on the other hand, that anyone can request the contractor to stop work if an unsafe practice is observed, but exercise caution when doing this. If it appears to be a situation that could result in injuries, it is best to act immediately. In less pressing cases, contact the Hazards Control or Industrial Safety representative for your area.

## MODIFICATIONS

During the MFTF project, a "Basic Maintenance Contract" with four subcontractors was established. This contract is being used as a prototype for other contracts planned for the future at LLNL. Jobs bid under this contract were fixed price, and each of the nearly 40 jobs completed met the criteria established for that job. This work involved construction or removing temporary walls, maintenance items, or other modifications that were not major new construction. The subcontractors would, usually once a week, walk through any jobs that were ready and submit bids to do the work. The turnaround from the time these jobs were reviewed by the contractors to the time work started averaged about 10 days. For this type of contract to work effectively, each job must be clearly defined and a good scope of work prepared before the requisition is released; change orders will negate any cost benefits otherwise realized with this arrangement. Also, before issuing the requisition, the requester should "walk the job" to establish the location of utility takeoffs, identify work that must be performed by others before the contract can start, identify any interferences or interfaces with activities in adjacent areas, and anticipate any other reasonable factors that could influence the job. The requester should, as a minimum, do the following:

- Prepare a sketch or drawing showing the modifications and the location of the work.
- Prepare a detailed scope of work noting all of the applicable items that were discussed under the "walk through" above.
- Establish a completion date. The contract used for MFTF allowed 2 to 5 working days for the contractors to see the job and submit a bid, and an additional 3 to 6 days before they were on site working the job.

- Estimate an expected job cost. It is important to establish a funding level so that the contract administrator can alert you if the bids are much higher than expected.

On large projects, it is advisable to have one person act as the administrator for these contracts. This administrator serves as the project's representative and must have a good working knowledge of the project and the facility. It is that person's responsibility to walk the job through with the contractors, act as the single point of contact for questions regarding the job, and perform the compliance inspection to ensure that the final product meets the requirements.

## COORDINATING CONSTRUCTION

Construction coordination is meant to eliminate or at least reduce problems that occur during the construction phase of a project. During the MFTF project, a committee was established that met once a week to discuss problems that occurred in the field, plan for major activities about to take place, and discuss safety-related issues. It was found that these meetings promoted cooperation between the contractors and LLNL personnel working in the field. The committee consisted of the subcontractors' field superintendents, LLNL line supervisors or the persons responsible for directing the work in the field, representatives from Hazards Control or Industrial Safety, the Construction Manager and Construction Inspector from Plant Engineering, and the project's facility project engineer, who chaired the meeting.

The committee identified action items and placed them on the agenda for consideration at meetings. Each item was identified by a serial number, the date it was placed on the list, a brief description of its present status, and the name of the person responsible to act on the item. At each meeting, the various items were reviewed to determine their status and pinpoint where help could be given to bring about resolution.

The Construction Coordinating Committee helped establish lines of communication that would not otherwise have existed, and it also helped the subcontractors accomplish their task by fostering understanding of how LLNL function and emphasizing that safety was one of the most important elements in meeting our goals.

# MODELING

A scale model expedites all phases of a project: conception, design, construction, and activation. A-three dimensional model enables those involved with design or other phases of a project to become oriented rapidly and to see the arrangement of a facility and the relationship of the hardware.

A Model Shop with full capabilities for building models exists at LLNL in Trailer 4230. Models built in this shop are scaled to the actual object and are generally made of plastic. The Model Shop was established in 1978 to support the MFTF project. The first model built was a crude representation of the building and the equipment as then planned. This model showed, to a first approximation, where all the equipment would fit. After this very crude beginning other models were built, professional model builders were hired, the shop's capabilities grew, and refinements in model building techniques continued to increase.

Models were found to be indispensable as proof of design. On numerous occasions, system models revealed interferences that would have resulted in costly field changes had they been installed as shown. Basic models were used for layouts of new equipment in existing areas. A major facility model was built and as new systems were designed, they were added to the model to determine if interferences existed. The facility model was used by the project for system reviews and by the contractors to plan the logistics of moving material, staging for work, and coordinating with other activities in adjacent areas.

Architectural models were used in the schematic phase of building design. These models showed the visual impact a structure would have on its surroundings. They were also used for room or area layout and for developing work-flow patterns or support areas for multiple users. An architectural model can be placed outdoors and oriented with respect to its cardinal points, and the lighting pattern can then be observed and optimized. Architectural models were built to assist in planning the location of a new facility with respect to an existing structures and to show that the planned roadways were adequate for emergency vehicle movement. The visual impact of a new structure could be demonstrated by photographing the model and comparing the picture with one taken from the same orientation of the actual area.

Equipment layout models were made of Styrofoam, which can be quickly formed into basic blocks representing the equipment being installed. These models were especially useful for an existing space where new equipment was to be installed. One useful technique was to identify with Styrofoam on the existing engineering model of the facilities a zone in which certain equipment was to be installed. This enabled other system designers to see where their equipment could be routed and established the "claimed" areas.

Engineering models, which are built to tolerances as small as practical, were used as a proof of design for many of the systems. It is the engineering model that reveals interferences, making it a investment that pays for itself many time over.

Industry standards exist for color-coding a model to identify the major utilities found in a building. To complement the model, systems can be color-coded for rapid identification. Photographic techniques are available that allow you to "walk through" a model, giving it full size realism. Hardware exists that establishes an interface between the plastic model and a CAD system to take advantage of both these design tools.

For a model to provide maximum advantage, it should be timely. The model should precede construction of the facility. In processing plants, this is the rule rather that the exception. A budget for the model should be established in the planning stages; it will provide one of the better returns that the project will experience, second only to successful results from the experiment or process being built.

## REVIEWS

The importance of reviews can not be overstressed. There are two types: continuous review of the requirements for the modification or construction of a facility, and formal reviews of the package that is prepared for bid. The requirements that have been collected from the the client should be reviewed to see where economies can be made by combining with existing services or by configuring a facility in a slightly different way that could be more beneficial in the long term. If there is a master plan for the area, it should be studied to see how the new additions will fit with what will be built in the future. Considerable time and money goes in to developing a master plan, and it is believed that the more effort that goes into seeing how new projects will fit into that plan, the more LLNL will save.

As has been mentioned, the requirements collected initially are subject to change and should be verified with the requester before the design package is developed too far. A review is necessary before Title 1 is started, and a more formal review is conducted before Title 2 design proceeds.

The techniques used in Value Engineering are very useful when reviewing how requirements for a project will be satisfied. Reducing elements to their most basic part and assigning a priority to that part has some surprising results. How to accomplish this is beyond the scope of this paper. There are many articles and books on the subject that can assist you in learning how to apply Value Engineering.

It is helpful to invite to design package reviews persons not associated with the project. Sometimes, the most obvious points are made by persons not close to the project. This is analogous to living in a house that has in one area a slightly high threshold that you meant to fix, but learned to live with. A visitor to your home will invariably trip at this threshold.

The design package to be reviewed should be distributed 2 to 3 days before the review is held so that individuals have a chance to scrutinize it before the formal presentation. Following up action items generated by the review is important in maintaining interest in and continued support of the reviews. All action items should be resolved as quickly as possible and a response returned to the originator of the item. The MFTF project used a form similar to that shown in Fig. 2 for this purpose.

## IMPACT ON UTILITIES

It is important to evaluate the impact of a new facility or project on distribution of site utilities. Start by determining the capacity of the services available. Next, find out if there are plans for others to be serviced by that same distribution. This information must be documented early in the planning of the project or facility and Plant Engineering must be made aware of the new loads to the service.

Review each system and list all the equipment energy consumption. An energy balance for the total project will show where the energy comes from and how it is expended. It is also valuable to make a time diagram of the total

DESIGN REVIEW ACTION REQUEST
(Reference MFTF Procedure QA-2)

__________ Serial No.

Date ________ Page___ of ___

REVIEW TITLE: ________________________________

ORIGINATOR

ORIGINATOR: (name, organization) ____________________
SUBSYSTEM: ______________________________
DESCRIPTION OF SUGGESTED ACTION: (one request per form)

P. E. OR OTHER ASSIGNED

COMMENTS BY: (name, group) ________________ DATE: ________
COMMENTS:

IMPACT EVALUATION:
TECHNICAL:
COST:
SCHEDULE:
IMPACT LEVEL:
FORWARDED TO A P M (date): ______

A. P. M.

RECOMMENDED DISPOSITION: (by APM/CM):

SIGNED: ________________ DATE: ________

PROJECT MANAGER

MFTF PROJECT OFFICE DECISION: APPROVE:___ DISAPPROVE:___ OTHER: ________
(explain)

ACTION ASSIGNED TO: ______________________ DUE DATE: ________
CCB ACTION REQUIRED? YES____ , NO ____ (CCB ACTION NUMBER ____ )
SIGNED: (PM) ______ DATE: ______

QA MANAGER

CLOSE-OUT COPIES TO: (name, date)
Originator ________________ APM ______________
Proj. Eng. ________________ Other ____________ QA Mgr. ______
FILE CLOSED OUT: (Date, QA Initial) __________

Figure 2. Design review action request form.

system showing when equipment is on or off line. In making this assessment, be certain to consider the building itself as a part of the system. After defining the services and the new loads, determine if a match exists. This is an important step. If any service is not adequate the project may face a schedule delay and a large expenditure to increase the capacity of that service.

The report Electrical Energy And The Cost For The Mirror Fusion Test Facility, UCRL-89435, was an early assessment of the MFTF project's electrical energy needs that helped to define how the machine would be operated. The data necessary for this report were also used to generate an energy balance for the project.

For utilities other than electrical power, there may be other means of satisfying the requirements without increasing the service to a building. For compressed air, as an example, accumulators may be able to provide sufficient volume. LCW systems may be able to take advantage of the duty cycle of an individual system by using large-volume mixing tanks to dissipate heat.

## STORAGE, STAGING, AND FIELD FABRICATION AREAS

Storage, staging, and field fabrication areas tend to be the stepchildren of a project. Each is important to the project's success, but their consideration as necessary items is often neglected.

Storage facilities are necessary for components and equipment on which early delivery is taken and for required spares. Completely secured inside storage areas for smaller components are best, since items do disappear during the construction phase of a project. There may be times when a portion of a new facility already constructed will not be activated until later in the project. Such areas are for the most part, completely under project control and could be used for locked storage. LLNL may also have some long-term storage space available at Camp Parks. If it is feasible to erect a building dedicated to component storage, that would be very desirable. However, be forewarned that any such building may be considered for other programmatic or support-service use by management.

Evaluate outside storage areas for large components for the impact that weather will have on access to the equipment. When soil in the area becomes saturated with rain, it may not be practical to move the equipment with a fork lift or a mobile crane. You may also want to consider the visual impact that equipment and hardware stored in the open may have on visitors being shown the site or attending occasions such as Family Day.

In spite of what the Construction Manager may say, staging areas for new buildings do not need to be very spacious. The size of buildings that are constructed in downtown San Francisco and the space available for staging provide an enlightening standard for comparison.

Large field fabrication areas similar to those used by the MFTF project are very difficult to obtain. These areas generally displace parking for private vehicles, which may have to be duplicated at the project's expense. Unfortunately, there is no trade-in value to the project after the area is abandoned. If cranes will be needed, consider the space necessary for their movement and the location of power lines. Also evaluate the problems of transporting the device that has been constructed from the field fabrication area to the facility. Consider overhead lines and the foliage along the route when selecting the site, and formulate plans on how they will be deactivated or removed and how traffic will be controlled.

## SCHEDULING AND ESTIMATING

In the world of major construction, scheduling seems to be sadly neglected. Reportedly, only 12% of all general contractors schedule. The "boiler plate" that accompanies contracts processed through LLNL's Plant Engineering Department includes all of the guidelines and requirements for submission of schedules by subcontractors, but obtaining timely schedules is a frustrating task. Most schedules supplied by construction contractors lack sufficient detail to establish an interface with other activities that are serially dependent on the construction.

When construction is independent of other project activities and a specific time period is allocated to complete the work, the only concern is the beginning and ending dates. But when construction interfaces with other activities and other subcontractors, the inner structure of the schedule is important. It is the project's responsibility to prepare an interface schedule for the subcontractors' use, showing the important milestones that must be met to avoid penalty payments.

Schedules must be realistic. Credibility slips very rapidly when dates originally touted to be important to other activities come and go without any apparent effect. When it is known that a date will slip, this information should be forwarded to the person responsible for maintaining or accelerating the affected schedule in order to meet a milestone. Almost without exception, it is better to complete an activity early; if possible, incentives should be offered for doing so.

Estimating is a necessary element of every project; it is very foolish to go shopping for something without a good idea of how much it will cost. To be timely, estimates must be completed before the design and specification phases of a project begin. Then, it is of paramount importance to monitor the work being performed in order to ensure that it stays within the estimate or the budget that has been allocated.

There are several methods of estimating: unit cost, trade, sixteen division, parameter, factor, range, and detailed. If you employ the "home estimate" method where you compare how long it would take you to do a similar task at home, be certain to moderate the parameters with intangible elements that exist such as pride of ownership and consequence of failure.

It has been found that the more estimaters practice, and the more they gain experience by comparing past estimates with actual costs, the more competent they becomes.

If you believe that an estimate for a project is unrealistic, check it right away rather than laboring under guidelines that you think are unobtainable.

## CONCLUSION

Perhaps the most important element in successfully preparing an area for a new project is communication between all parties involved. To some degree, the model that was constructed of the MFTF facility helped accomplish this. As new systems were added to the model, the various system designers were able to see the impact that these systems would have on adjacent areas. Another strong element in maintaining good communication in a multidisciplined project is to ensure that reviews during the course of the project are open and well advertised.

The ability to remain flexible is also a valuable asset, especially when dealing with requirements that tend to be very liquid during the conceptual and early stages of a project. Equally important, there comes a time when these requirements must solidify, and the consequences of changing them after that point needs to be stressed to those who contribute to their formulation.

PQ512104/MM